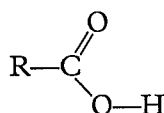


## 14.2 AMINO ACIDS

We saw in Section 5.16 that *alkanoic acids* had the general structure:

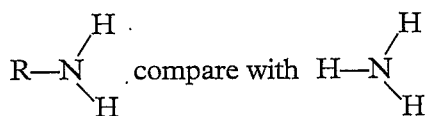


In those chapters R was any alkyl group. More generally R can be any carbon-containing group (not just alkyl) in which case the compound is called a *carboxylic acid*.

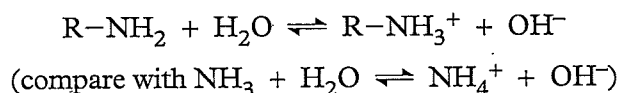
Another class of simple carbon compounds is called *amines*. These are derivatives of ammonia.

**Amines** are compounds in which one or more carbon-containing groups (such as alkyl groups) replace one or more H atoms in an ammonia molecule.

If one H of ammonia is replaced by a carbon-containing group, we get the structure:



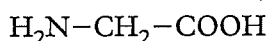
Like ammonia, amines are weak bases. They undergo the following equilibrium reaction:



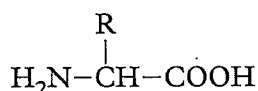
We call  $-\text{NH}_2$  the **amine functional group**.

**Amino acids** are compounds that contain both an amine and a carboxylic acid functional group.

The simplest amino acid is glycine:



There is a whole family of amino acids with the general structure:



where R is a carbon-containing side chain.

Proteins are long-chain molecules with thousands of amino acid molecules of this general structure joined together. (This is discussed below.)

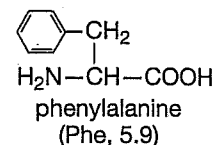
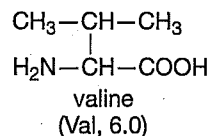
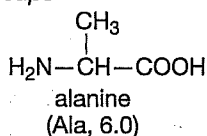
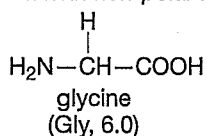
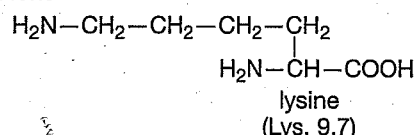
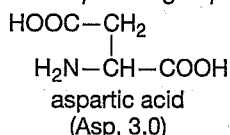
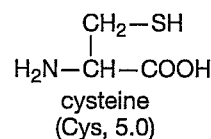
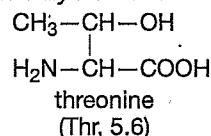
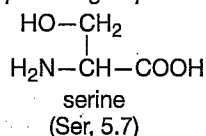
There are 20 amino acids commonly found in proteins. Some of these are shown in Table 14.1. They fall into three broad groups; amino acids with:

- non-polar R groups (alkyl or similar)
- polar R groups that are capable of forming ions; these have a  $-\text{COOH}$  or  $-\text{NH}_2$  group *additional* to the normal ones in the amino acid
- polar R groups that do not generally form ions; the simplest of these contain polar  $-\text{OH}$  or  $-\text{SH}$  groups as part of R.

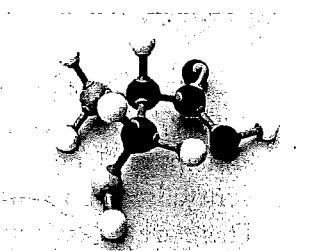
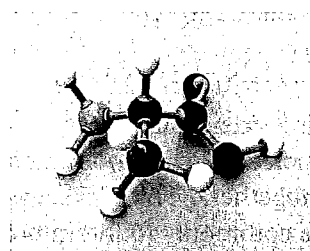
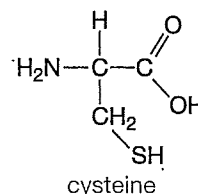
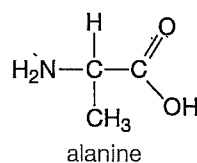
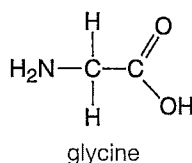
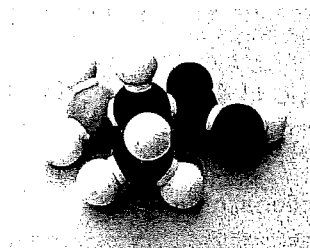
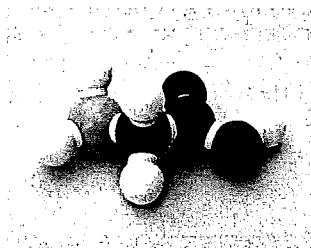
Molecular models of three simple amino acids are shown in Figure 14.1.

**TABLE 14.1 Common amino acids found in proteins**

(usual abbreviations and isoelectric points (Section 14.10) are given in brackets under the name)

**a with non-polar R groups****b with polar R groups that form ions****c polar R groups that do not generally form ions****FIGURE 14.1**

Space-filling and ball-and-stick models of glycine, alanine and cysteine along with structural formulae drawn with approximately similar orientations. Black is C, white, H, red, O, blue, N and yellow, S

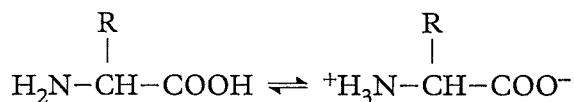


The occurrence of an acidic and a basic group on the one molecule leads to the possibility of an ionic structure for amino acids.

### 14.3 ZWITTERIONS

So far we have written amino acids as neutral molecules as in Table 14.1. However the  $-\text{COOH}$  group, being acidic, tends to lose a proton, while the amine group,  $-\text{NH}_2$ , being basic, tends to gain a proton. Hence in solution,

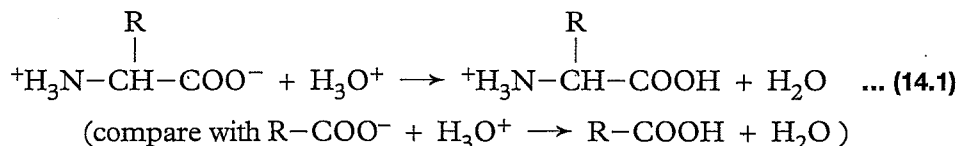
amino acids exist as an equilibrium mixture of neutral molecules with a dipolar ion:



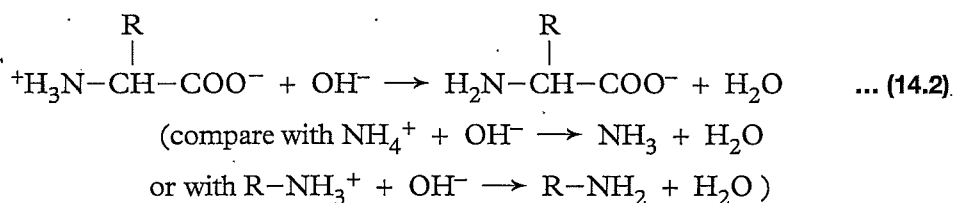
This dipolar ion is called a zwitterion. Most amino acids exist primarily as zwitterions.

Because of this dipolar structure of amino acids, they are crystalline solids with relatively high melting points, and they are soluble in water.

Because the  $-\text{COOH}$  group is a weak acid and the  $-\text{NH}_2$  group is a weak base, amino acids take on different forms in solutions of different pH. In acid solution, say pH 2 to 3, the zwitterion changes to a cation:



In alkaline solution it changes to an anion:



## Exercises

- 1 A certain amino acid contained 40.4% carbon, 7.9% hydrogen and 15.7% nitrogen. The balance was oxygen.
  - a Calculate the empirical formula.
  - b Draw the structural formula of the simplest amino acid that could have this empirical formula.
- 2 Glycine and alanine are the first two members of a homologous series of 'straight-chain' amino acids. Draw structures for the next two members of the series.
- 3 MSG (monosodium glutamate) is widely used as a flavour-enhancing agent (often in Chinese food). It is the sodium salt of glutamic acid. Glutamic acid is an amino acid with a propanoic acid side chain. Draw the structure of glutamic acid and hence of MSG. Why is it called 'monosodium'?
- 4 For each of the amino acids:
 

a glycine	b alanine	*c cysteine	*d lysine
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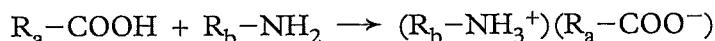
 from Table 14.1, draw the structural formula of the zwitterion form of the molecule.
- 5 Draw the structures you would expect for (a) valine (b) aspartic acid (Table 14.1) in solutions of pH (i) 2 and (ii) 11.
- 6 a Draw the structural formula of the main species present in a solution of serine (Table 14.1) in water.
  - b Draw the structural formula of the main species present when:
    - i 1.00 mol of each of serine and sodium hydroxide is dissolved in 2.00 L water
    - ii 1.00 mol hydrochloric acid is added to the solution in (i)
    - iii another 1.00 mol HCl is added to the solution in (ii).



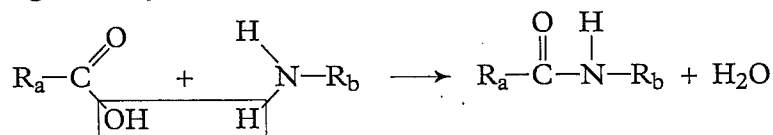
- 7 Glycine can be used as a buffer at pHs around 6. Explain why (with equations).
- \*8 Alanine is amphoteric. Write equations which show this.

## 14.4 PEPTIDES

As expected from our knowledge of acids and bases, an amine reacts with a carboxylic acid to form a salt:

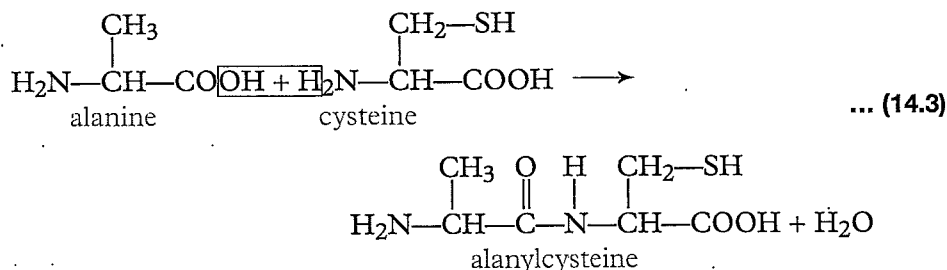


However *under certain conditions an amine reacts with a carboxylic acid by eliminating water to form what we call an amide*:



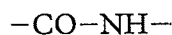
This amide product is a stable covalent compound with no acid or base properties at all.

Pairs of amino acid molecules undergo this same reaction. For example, alanine reacts with cysteine:



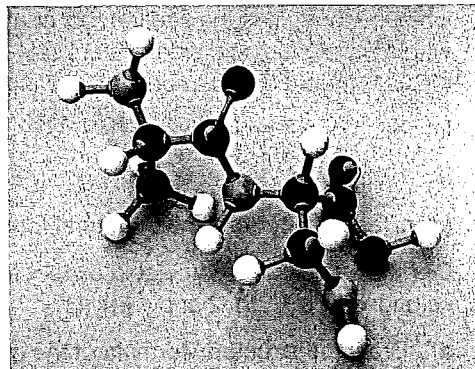
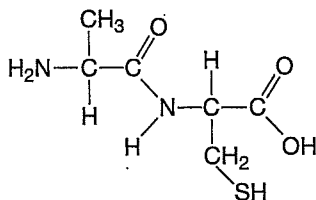
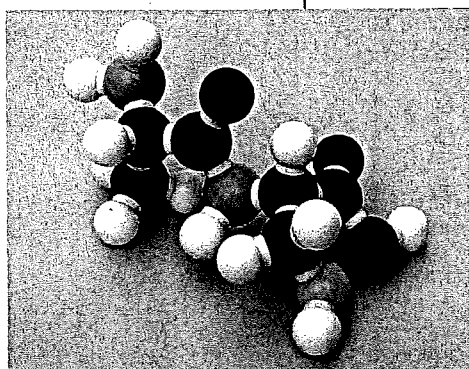
The compound formed when two amino acids react together is called a **dipeptide**. This amide linkage between two amino acids is called a **peptide bond**.

The peptide link which we have drawn out in full in Equation 14.3 is often written more concisely as:



Molecular models of alanyl cysteine are shown in Figure 14.2.

FIGURE 14.2  
Space-filling and ball-and-stick models of alanyl cysteine, the dipeptide formed between alanine and cysteine. Colours are as in Figure 14.1



Our dipeptide in Equation 14.3 still has terminal COOH and amine groups, so it can join to other amino acids. For example, with another molecule of alanine we get: